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Carbon Materials Research

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14. ABSTRACT

A basic research study in carbon materials for propulsion applications led to research in seemingly diverse areas, which include carbon-carbon composite fabrication, oxidation protection of carbon, microelectromechanical (MEMs) devices, and surface tension phenomenon. Carbon-carbon composites are the material of choice in many high temperature thermostructural applications, such as, rocket nozzles and exit cones, missile nosetips, and leading edges of hypersonic vehicles. Although these material are stronger than steel, stiffer than steel, lighter than aluminum, and resistant to thermal shock, they are susceptible to oxidation above 450°C. In addition they are very costly due principally to the process of densification in which a carbon matrix is placed among the carbon fibers in a perform that has been constructed to have certain mechanical properties. This study has addressed both the problems of oxidation resistance and cost of carbon-carbon composites. In addressing the issue of cost, a completely new and innovative densification approach called In Situ densification was conceived and implemented. This process has the duel advantage of both a significant cost reduction as well as a significant reduction in the time needed to densify these composites. In addressing the oxidation protection of carbon-carbon composites, the entirely new field of microtube technology was born. This technology allows the fabrication of free-standing or imbedded microscopic tubes that can possess any cross-sectional or axial shape. Numerous devices have been conceived and fabricated utilizing this technology. Since surface tension is a dominant force at microscopic dimensions, devices employing non-wetting liquids and surface tension were conceived and fabricated. During the fabrication of some of these devices, an entirely new wetting phenomena was discovered. That is, it is possible to make a non-wetting surface wetting and a wetting surface to be non-wetting simply by changing the geometry of the surface that the liquid contacts.

15. SUBJECT TERMS
carbon; carbon materials; propulsion; carbon-carbon composites; rocket nozzle; exit cone; missile nosetip; hypersonic vehicle; oxidation resistance; cost; densification; MEMs; surface tension; microtube

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FOREWORD

This final report, entitled "Carbon Materials Research," presents the results of a research study performed under JON 2308M1B3 by AFRL/PRSM, Edwards AFB CA. The Project Manager for the Air Force Research Laboratory was Dr. Wesley P. Hoffman.

This report has been reviewed and is approved for release and distribution in accordance with the distribution statement on the cover and on the SF Form 298.

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1.0 EXECUTIVE SUMMARY

1.1 Abstract

A basic research study in carbon materials for propulsion applications led to research in seemingly diverse areas, which include carbon-carbon composite fabrication, oxidation protection of carbon, microelectromechanical (MEMs) devices, and surface tension phenomenon.

Carbon-carbon composites are the material of choice in many high-temperature thermostructural applications, such as rocket nozzles and exit cones, missile nosetips, and leading edges of hypersonic vehicles. Although these material are stronger than steel, stiffer than steel, lighter than aluminum, and resistant to thermal shock, they are susceptible to oxidation above 450°C. In addition, they are very costly, due principally to the process of densification in which a carbon matrix is placed among the carbon fibers in a preform that has been constructed to have certain mechanical properties.

This study has addressed both the problems of oxidation resistance and the cost of carbon-carbon composites. In addressing the issue of cost, a completely new and innovative densification approach called In Situ Densification was conceived and implemented. This process has the dual advantage of both a significant cost reduction and a significant reduction in the time needed to densify these composites.

In addressing the oxidation protection of carbon-carbon composites, the entirely new field of microtube technology was born. This technology allows the fabrication of free-standing or imbedded microscopic tubes that can possess any cross-sectional or axial shape. Numerous devices have been conceived and fabricated utilizing this technology. Since surface tension is a dominant force at microscopic dimensions, devices employing non-wetting liquids and surface tension were conceived and fabricated. During the fabrication of some of these devices, an entirely new wetting phenomena was discovered. That is, it is possible to make a non-wetting surface wetting and a wetting surface to be non-wetting simply by changing the geometry of the surface that the liquid contacts.

1.2 Summary and Recommendations

The In Situ Densification process produces a very high quality matrix at a fraction of the cost and in a fraction of the time required by current commercial processes. The electrical and thermal conductivity of these composites produced by the In Situ Process is equivalent to the conductivity of the best commercial composites. In addition, the density of these composites is more uniform than what is available with commercial composites. This is a result of the complete penetration of the liquid matrix precursor into the fiber preform, which is one of the keys of this process. These composites have a wide range of uses in both DOD and commercial applications because of their excellent properties, low cost, and rapid processing time. Application of these composites into full-scale applications, such as exit cones, should be pursued.

Microtubes also have a wide range of application in both DOD and the commercial sector. Applications – including cooling, separation technologies, venting and sensors – should continue to be pursued.

In normal situations, to change how a liquid interacts with a surface, it is necessary to change either the character of the surface by applying a coating or a surface treatment or the liquid by, for example, adding a surfactant or solvent. The geometric surface wetting phenomena allows you to change the wetting character of a surface without changing the character of either the surface or the surface tension of the liquid. This is done simply by physically modifying the surface so that there is an angular surface. This phenomena has important applications in areas as diverse as heat exchange and catalysis.

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